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Evaluation of Composted Sewage Sludge Application to Soil

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Abstract

The physicochemical properties of soil amended by composted sewage sludge and the growth of Tall Fescue in amended soil were investigated by pot-scale experiments. The incubation experimental results showed that organic nitrogen and ammonia in soil can be mineralized and nitrified simultaneously during 60 d, both of which stayed at relatively stable levels afterwards. The concentration of NO3--N in amended soil was significantly higher than that in the soil without CSS. The pH of amended soil kept stable whereas the electric conductivity varied with the evolution of the concentration of organic matters resulted from nutrients mineralization and immobilization. After a slow release of phosphorus in the initial 100 d, there was a sharp decrease in the concentration of total phosphorus in amended soil, which meant a fast mineralization of phosphorus-containing organic compounds. The planting assays of Tall Fescue showed that the highest amount of biomass in 180 d was obtained at a dosage of 15 %. However, during the initial 60 d, a dosage of 5% led to a greatest biomass growth. Based on the uptake and recovery of N and P from amended soils, a CSS dosage of 5% in amended soil was suggested for a good growth of Tall Fescue.

Keywords: Composted sewage sludge; Soil, Tall Fescue, Nutritive element

1. Introduction

Sewage sludge is an inevitable by-product derived from urban wastewater treatment, in which a large number of organic matters (OM), nutritive elements and also harmful matters were accumulated. Composting

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is a simple and cost-effective alternative for sewage sludge treatment; it produces a stabilized residue and disinfects pathogens. Composted sewage sludge (CSS) therefore could be utilized as a soil amendment to increase the content of OM, which plays a crucial role in improving the physical, chemical and biological properties of soils, e.g. water holding capacity, aeration and productivity.

The application of CSS in soil as a nutritive amendment requires a well understanding of the dosage to avoid serious problems caused by CSS overdosing. CSS supplementation for the nitrogen demand of crops can lead to excessive phosphorus in soil because of the low ratio of N:P in the biosolid compared with inorganic fertilizers (White and Collin, 1982). Cheng et al. (2007) recommended that a dose of CSS≤20% can be used as soil amendments to avoid the affect of soluble salts contents.

In this study, pot experiments were adopted to evaluate the effect of physicochemical properties of amended soil in which CSS is added at different dosages and the growth of Tall Fescue according to the dry weight and the uptake of nutrimental element of Tall Fescue.

2. Materials and methods

2.1. Composted sewage sludge and Soil

The CSS taken from a local wastewater treatment plant (Beijing, China), was subject to a windrow composting process with spent mushroom for 3 months. The original soil was collected from a bare land at a depth of 0-15 cm on the campus of Beijing Forestry University. The CSS and soil were air-dried and ground to pass through a 2-mm sieve, and were homogenized.

2.2. Experimental Design

Aerobic incubation experiments of soil were made with CSS amendments in the greenhouse center in Beijing Forestry University. Plastic pots were filled with 700 g of the mixture of CSS and soil supported by gravel at the bottom. Four CSS/(CSS + soil) ratios of 5%, 10%, 15% and 20% were studied and the samples were abbreviated as S1, S2, S3 and S4. A same group of CSS-amended soil samples were employed to study the effects of CSS on the growth of Tall Fescue by using pot experiments. The pots were sowed with 0.7 g of seeds and were periodically irrigated.

2.3. Analysis

pH was measured after mixing the sample with deionized water at a ratio of 1:2.5. EC was measured with a soil/DI water ratio of 1:5. Total nitrogen was determined by Kjeldahl digestion–distillation method. NH4+–N were examined in KCl extracts. Nitrate–N were examined in CaSO4 extracts using a UV–Vis spectrophotometer. Total phosphorus was determined by a spectrophohometer. Soil OM was determined after oxidizing samples with K2Cr2O7 in concentrated H2SO4.

3. Results and discussion

3.1. Physicochemical properties of soil and composted sewage sludge

The Physicochemical properties of original soil and CSS were as shown in Table 1.

Table 1 Physicochemical properties of original soil and CSS

physicochemical properties	Soil	CSS
pH	7.4	7.8
EC (μs/cm)	747	3950
TOC (mg/g)	14.12	365.79
Ammonium nitrogen (mg/kg)	111.27	7091.3
Nitrate nitrogen (mg/kg)	6.83	197.39
Organic nitrogen (mg/kg)	51.73	15015.37
C/N	87.44	16.4
TP (mg/g)	0.33	7.0

3.2. Physicochemical properties of amended soil at different dosage of CSS

3.2.1. pH

The pH of soil stayed at relative stable level. There were no obvious differences in the pH among the soil samples with CSS dosage increasing or during the incubation period for a same sample (Table 2).

Table 2 pH of soil

	0 d	60^{th} d	100^{th} d	135^{th} d	185^{th} d
Control	7.50±0.03a	7.63±0.03b	7.40±0.02b	7.30±0.07c	7.35±0.10c
S1	7.42±0.06a	7.81±0.06a	7.31±0.04c	7.68±0.18a	7.82±0.17a
S2	7.44±0.02a	7.85±0.04a	7.46±0.06b	7.68±0.08a	7.74±0.06a
S3	7.46±0.08a	7.82±0.03a	7.52±0.08a	7.59±0.06b	7.80±0.09a
S4	7.48±0.07a	7.63±0.06b	7.36±0.06c	7.54±0.06b	7.54±0.08b

3.2.2. EC

Higher EC levels were seen in the soil samples with greater CSS amendments as shown in Fig. 1. The increases in EC were apparently attributed to the CSS supplementation (EC: 3950 μS/cm) because the EC of both the raw soil (747μS/cm) and the irrigation water (469 μS/cm) were in much lower levels. EC of water extracts of good fertilizers was suggested to never exceed the salinity limit of 3000 μS/cm (Amir et al,2005).

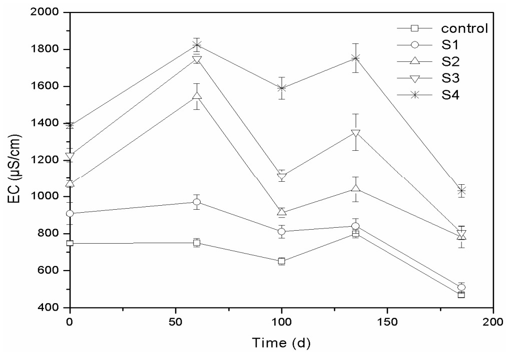

Fig. 1 Evolution of EC in soil with time

3.2.3. OM

The content of OM showed opposite fluctuation to EC, significant difference（$p<0.05$） was observed on different fertilizer dosages. The increase in OM values of soils seemed to be correlated to growing compost applications dosage initially (control<S1<S2<S3<S4). There was an increase in OM during 60-100d. 100 d later, OM decreased in all treatments with time (Fig. 2). During 135-185 d, the OM decreased sharply. José M. et al., (2007) also found the same trend in the green house experiments.

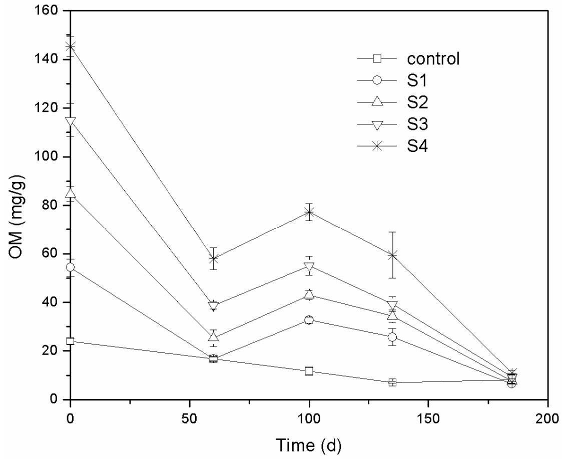

Fig.2 Evolution of OM in soil with time

3.2.4. Nitrogen

There was a great variety in nitrogen during the incubation experiments. The CSS had a low C/N ratio suggesting a rapid release of N. NO3--N increased sharply, with no significant differences among the soil samples amended with different CSS doses (Fig.3c).Contents of NH4+-N and organic nitrogen decreased while contents of NO3- increased, showing mineralization and nitrification simultaneously occurred. The maximum concentration of NH4+-N in soil tolerated by nitrifying organisms is between 400 and 800 mg/kg. S3 and S4 treatments were beyond this range (Fig. 3b), indicating the nitrification ratio was slow.

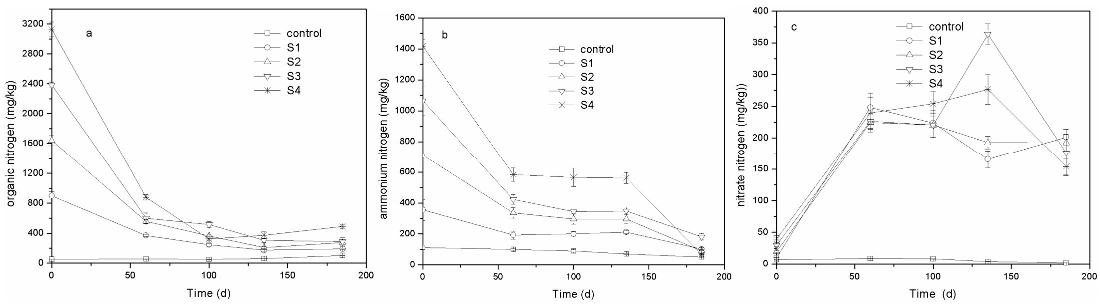

Fig. 3 Evolution of organic (a), ammonium (b) and nitrate (c) nitrogen in soil

It can be seen from Fig.3a and Fig.3b that contents of NH_4^+-N had similar tendency with organic N. Both of them had a slight decrease, showing relatively stable state during 60-135d. NO3--N and NH4+-N content in S4 treatment showed linear relation with time. Although content of NH4+-N in S4 treatment was higher than that in S3 treatment, the increase of NO3--N in S4 treatment was lower than in that S3 treatment.

Table 3 Average daily mineralization rate in amended soil (%)

	S1	S2	S3	S4
P1	0.98±0.03a	1.10±0.02a	1.20±0.04a	1.25±0.05a
P2	0.34±0.02b	0.30±0.01b	0.90±0.02b	0.45±0.02b
P3	0.23±0.01c	0.27±0.02b	0.25±0.01c	-0.05±0.02c
P4	-0.04±0.01d	-0.08±0.01c	0.01±0.01d	-0.07±0.01c

P1, P2, P3 and P4 represented stages of 0-60, 60-100, 100-135 and135-185d, respectively.

The organic N in compost consisted of two organic fractions with different degrees of stability: labile organic N, rapidly mineralized in soil, and resistant organic N, slowly decomposed in soil. The first stage had the biggest rate, and the decomposed rate reduced with time, which meant that as N mineralization proceeds, mineralizable N resistance increased and thus the rate of mineralization decreased (Table 3).

3.2.5. Phosphorous

P played the role of macronutrients for crops and microorganisms, which can limit vegetative growth. At prophase ,significant increases ($p < 0.01$) of phosphorus content were measured in soil after an increasing dose of compost (control <S1<S2<S3<S4), the decrease in TP concentration presented linearity, attributed to the soluble phosphate's percolation through soil. At 185th day, the TP content decreased to 0.12-0.26 mg/g, with no significant difference among different doses (Fig. 4), thus the phosphorous saturation was likely to explain P losses.

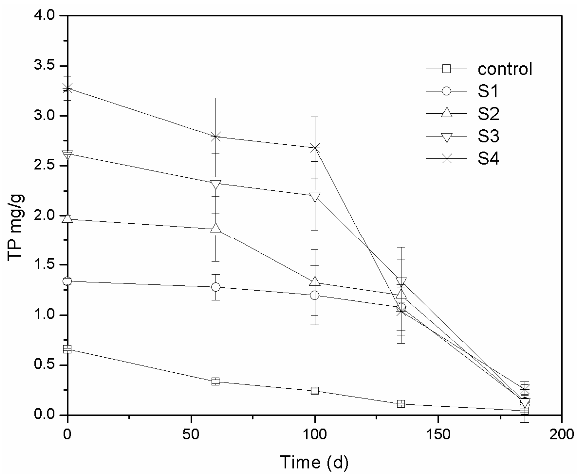

Fig.4 Evolution of TP in soil with time

3.3. Effects of Composted sewage sludge Dose on growth of Tall Fescue

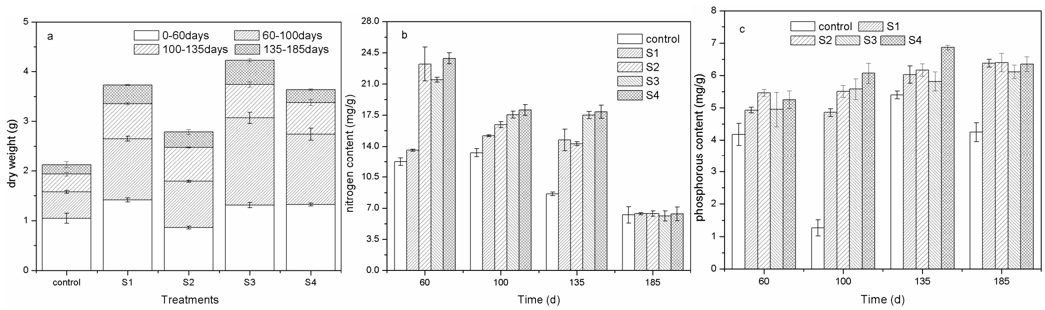

Fig.5 Dry weight yields and mean nutrient contents of Tall Fescue

Fig.5 showed the changes of dry weight for Tall Fescue growth in different amended soils. All treatment pots consistently produced higher yields than the control in the whole experimental period. During the preliminary 60d, the biggest biomass of Tall Fescue was obtained at S1 among all treatments. During the whole experimental period, nitrogen content in Tall Fescue grew in treated soils were higher than that in control soil except the last stage. At the same doses, the first stage had the highest nitrogen content, and the mediate two stages had a similar content, but lower than the first stage (Fig.5a,b). P concentrations in the Tall Fescue planted in treated soils were normally higher than those in the control. The P uptake contents in first stage and the second stage were higher than the last two stages (Fig.5c).

4. Conclusions

The application of CSS had a great influence on the physicochemical properties of soil. Significant increases in electric conductivity were measured at the 20% ratio of CSS in the initial period. Not only total nitrogen content in treated soil increased after the application of CSS, but also the availability of nitrogen was improved. Compositive MIT and nitrification occurred during incubation. However, excessive applications of CSS had a potential N loss as nitrate or other nitrogen oxides.

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